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Original article

A systematic literature review of US definitions, scoring systems and validity according to the OMERACT filter for tendon lesion in RA and other inflammatory joint diseases

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Abstract

Objective. To present the published data concerning the US assessment of tendon lesions as well as the US metric properties investigated in inflammatory arthritis.

Methods. A systematic literature search of PubMed, Embase and the Cochrane Library was performed. Selection criteria were original articles in the English language reporting US, Doppler, tenosynovitis and other tendon lesions in patients with RA and other inflammatory arthritis. Data extraction focused on the definition and quantification of US-detected tenosynovitis and other tendon abnormalities and the metric properties of US according to the OMERACT filter for evaluating the above tendon lesions.

Results. Thirty-three of 192 identified articles were included in the review. Most articles were case series (42%) or case–control (33%) studies describing hand and/or foot tenosynovitis in RA patients. The majority of older articles used only B-mode, whereas the most recent studies have incorporated Doppler mode. Definition of tenosynovitis or other tendon lesion was provided in 70% of the evaluated studies. Most of the studies (61%) used a binary score for evaluating tendon abnormalities. Concerning the OMERACT filter, 24 (73%) articles dealt with construct validity. The comparator most commonly used was clinical assessment and MRI. There were few studies assessing criterion validity. Some studies evaluated reliability (36%), responsiveness (21%) and feasibility (12%).

Conclusion. US seems a promising tool for evaluating inflammatory tendon lesions. However, further validation is necessary for implementation in clinical practice and trials.

Key words: systematic literature review, ultrasound, tenosynovitis, tendon lesions, rheumatoid arthritis, inflammatory arthritis, OMERACT filter.

CLINICAL SCIENCE

Introduction

RA is a chronic inflammatory disease characterized by synovial inflammation (i.e. synovial proliferation and angiogenesis), which can damage cartilage, bone, ligaments and tendons [1]. In addition to IA synovitis, tenosynovitis is a common pathological feature in RA and other inflammatory joint diseases [2, 3]. The proliferation of the tenosynovium can produce tendon adhesion and rupture with consequent severe joint function impairment [4].

Assessment of inflammatory activity and severity of RA and other chronic inflammatory arthritis is essential in rheumatological practice to enable therapeutic decisions

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and to evaluate disease outcome and response to treatment. Within the last decade, technological improvements in the diagnostic capacity of musculoskeletal (MS) US have led to an increasingly important role of this imaging modality in the evaluation and monitoring of patients with chronic inflammatory arthritis based mainly on the fact that it is definitely more sensitive than clinical examination for detecting synovitis [5–8]. Grey-scale (GS) US with Doppler technique allows direct assessment of IA and periarticular inflammatory activity and structural damage in inflammatory arthritis such as joint effusion and synovial hypertrophy, tenosynovitis, synovial and tenosynovial vascularity, tendon and ligament lesions, bone erosions and articular cartilage damage. MSUS is a routinely available, multiplanar, dynamic, non-invasive, portable and relatively inexpensive bedside imaging modality with high patient acceptability. This technique facilitates the scanning of all peripheral joints as many times as required at the time of consultation.

Several studies have proven that MSUS is accurate for detecting joint effusion and synovial hypertrophy as compared with MRI [9] and direct arthroscopic visualization [6]. Colour Doppler (CD) and power Doppler (PD) techniques are able to detect synovial flow, which is a sign of increased synovial vascularization. This has been supported by a number of studies on their criterion (i.e. concurrent and predictive) validity, with histological findings [10], MRI [11, 12] and radiographic outcome [13] as the gold standard, and their construct validity compared with clinical and laboratory parameters [8] in RA. Recent cohort studies have demonstrated a significant improvement of synovitis evaluated by GSUS and CDUS or PDUS, parallel to clinical and laboratory changes in RA patients treated with effective therapy, mainly biologic agents [14–16].

Several scoring systems (i.e. qualitative, semi-quantitative and quantitative) for assessing joint synovitis with GS or Doppler US in any number of scanned joints have been used in the literature. Most studies have evaluated IA synovitis and only a few studies have incorporated tenosynovitis in the joint US assessment [17]. In the same way, a variety of US assessments, including from a comprehensive number of joints to a reduced number of target RA joints such as wrist, hand or toe joints have been published [17]. Two feasible reduced-joint US assessments (i.e. 12 joints and 7 joints) have been shown to be equivalent to the comprehensive US evaluation with respect to metric properties (i.e. validity, reliability and sensitivity to change) [18, 19].

Since 2004, the OMERACT US Task Force, an international collaborative group of MSUS experts, has worked to address the metric qualities of MSUS in RA and other inflammatory arthritis according to criteria specified by the OMERACT filter [20]. In 2005, the OMERACT group for MSUS proposed agreed definitions for inflammatory pathologies [21], including bone erosion, SF, synovial hypertrophy, enthesopathy and tenosynovitis. Tenosynovitis was defined as hypoechoic or anechoic thickened tissue with or without fluid within the tendon sheath, which is seen in two perpendicular planes and which may exhibit Doppler signal. Over the last 6 years, the group has developed a standardized scoring system for synovitis in RA that combines GS and PD in a 0–3 scale and has demonstrated intra- and inter-observer reliability and is applicable to all joints and consistent between machines [22]. However, few data are available on the implementation of the OMERACT definition of US tenosynovitis in clinical practice and research, the quantification of US-detected tenosynovitis and other tendon lesions, and the metric properties of US in the assessment of the above tendon abnormalities in inflammatory arthritis. Now the group work is focusing on, among other activities, the use of MSUS for evaluating tendon inflammation and tendon damage in RA.

The objectives of this literature review were the following: (i) to assess US definitions and scoring systems used in the literature for tenosynovitis and other tendon lesions in inflammatory arthritis (i.e. RA, PsA, SpA and other type of inflammatory arthritis); and (ii) to assess the metric properties according to the OMERACT filter [21] of US in the detection and quantification of tendon inflammation and damage in the above diseases in the published literature.

Methods

Study selection criteria

We included original articles involving humans published in English between January 1966 and September 2011 that incorporate US for assessment of tenosynovitis and other tendon lesions in patients with RA, PsA, SpA or inflammatory arthritis. Reviews, letters, editorials and abstracts of scientific congresses were noted but not included.

Data source and search strategy

The search of articles was performed in the PubMed, Embase and Cochrane Library databases. The above search of articles was performed using the following key words: (Ultrasound OR Ultrasonography OR Sonography OR Power Doppler OR Doppler) AND (Rheumatoid Arthritis OR Psoriatic Arthritis OR Spondyloarthritis OR Inflammatory Arthritis) AND (tenosynovitis OR tendon abnormality OR tendon lesion OR tendinosis OR tendinitis OR tendon tear OR tendon rupture) with limits (language = English, humans only, from 1 January 1966 to 30 September 2011 for PubMed, 1 January 1984 to July 2011 for Embase and no limitation of date of publication for the Cochrane Library database). The articles that included only assessment of the shoulder or that were limited to the enthesis were excluded. For the three searches, key words referred to medical subject heading (MeSH) terms or if not available referred to key words present in the title/abstract. Titles, abstracts and full reports of the identified articles were systematically screened by one author (M.A.) with regard to inclusion and exclusion criteria. Furthermore, a manual search of secondary sources including article references was also performed.

Data extraction

All selected articles were reviewed by two authors (M.A. and E.N.) and all data were extracted using a standardized template that was specifically designed for this review. The data were collected on an Excel sheet. The reviewers scanned the following data from all studies: type of study, disease, number of patients, number of controls, blinding, tendons studied, US definition of tenosynovitis and other tendon abnormalities, components of tendon lesions studied (e.g. tenosynovitis/synovial sheath effusion/synovial hypertrophy, tendinosis/tendinitis, peritendinitis/paratenonitis, tendon tear/rupture), US mode used (i.e. GS, CD or PD), scoring system [i.e. binary (yes/no), semi-quantitative and quantitative] for GS and Doppler findings, US scanning method (i.e. probe characteristics, patient position, probe placement, scanning protocol).

Each included article was analysed in order to determine whether or not it fulfilled some aspect of validity according to the OMERACT filter [20]. The following metric properties were independently evaluated: construct validity, criterion (i.e. concurrent and predictive) validity, discriminant validity (i.e. intra- and inter-observer reliability, and sensitivity to change or responsiveness) and feasibility. Blinded design for assessing metric properties was also noted. Criterion validity was considered when US findings were concurrently or predictively compared with a gold standard. Construct validity was considered when US findings were compared with other measures of the same pathological phenomenon. Two aspects of the reliability were assessed: acquisition and reading of US images.

Statistical analysis

We used descriptive statistics to report data. Frequencies and percentages were shown for categorical variables.

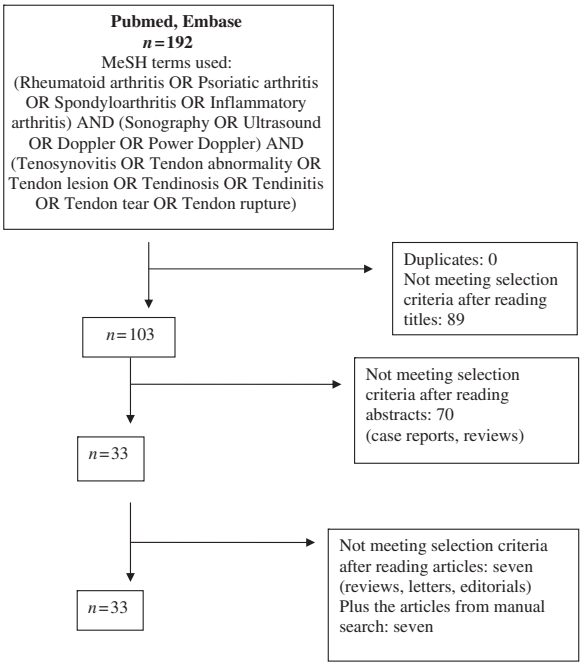
Results

The search yielded 192 citations, of which 89 were rejected after reviewing the title. Subsequently, 103 abstracts were reviewed to determine whether they met the inclusion criteria for this review. Thirty-three full-text articles were reviewed to finally identify 26 articles [23–48] meeting the inclusion criteria. From the manual search performed, seven articles [14–16, 18, 19, 49, 50] were also included. Fig. 1 shows the flowchart of the systematic review process.

Characteristics of the studies

Characteristics of the studies are shown in Table 1. Case series studies were the most common type of study (14; 42.4%) [23, 28, 29, 33, 36, 38, 41, 42, 44, 45, 47–50] followed by case–control studies (11; 33.3%) [24–27, 30–32, 34, 37, 39, 40] and cohort studies (8; 24.2%) [14–16, 18, 19, 35, 43, 46]. Most studies (29, 87.9%) included RA patients [14–16, 18, 19, 23–29, 31, 33–36, 38–47, 49, 50], 8 (24.2%) studies included PsA patients [19, 27, 28, 32, 37, 38, 40, 47] and 7 (21.2%) studies included patients with different inflammatory

Fig. 1 Flow chart of the search strategy and study selection.



diseases (i.e. PsA, SpA, ReA, Behçet's disease, gout, RS3PE and CTDs) [27, 28, 30, 34, 36, 38, 45]. The sample size ranged from 4 to 278, but in most of the studies comprised between 20 and 30 patients.

Tendons assessed

The hand was the anatomic area most frequently studied (23; 69.7%) [14–16, 18, 19, 23, 24, 26, 30, 32, 33, 35–38, 39, 40, 43, 45–47, 49, 50], followed by the ankle and foot (16; 48.5%) [18, 25, 27–29, 31, 32, 34, 36, 38, 41, 42, 44, 46, 48, 50]. Six (18.2%) papers evaluated tendons of both hand and foot [18, 32, 36, 38, 46, 50]. Regarding the hand, the tendons most commonly assessed were the flexor and the extensor tendons of the fingers. The tibialis posterior and anterior tendons and the peroneal tendons were the tendons more often studied in the ankle and foot.

Tendon abnormalities

Most of the articles focused on tenosynovitis (87.9%). Other tendon abnormalities assessed were tendon rupture, tendinosis, tendinitis, paratenon or peritendinous inflammation, enthesitis, tendon nodules and calcification.

Five studies [14, 15, 16, 18, 49] were selected because hand and/or foot tenosynovitis was included in a PDUS assessment of joint inflammation (1–44 joints). However, in these studies, tendons were not separately evaluated but were included in a global score on GS and PD at each studied joint.

US mode

In 15 (45.5%) studies [23–33, 36, 39, 42, 43] only GS (i.e. B-mode) was used, whereas in 18 (54.5%) articles both GS and PD (17; 51.5%) [14–16, 18, 19, 34, 37, 38,

Table 1 Characteristics of the studies, tendons assessed, definitions and descriptions of lesions and quantification systems used

Author	Type of study	Disease	Sample size	Tendons assessed	Tendon lesions assessed	US mode	US definition of lesions	US components of lesion	Quantification system
De Flaviis *et al.* [23]	Case series	RA	20	Flexor and extensor tendons of the hand and wrist	Tenosynovitis, tendon rupture	GS	Yes	Anechoic or hypoechoic enlarged tendon sheath for tenosynovitis; no description for rupture	Binary
Fornage [24]	Case–control (unblended)	RA	16 (15 healthy controls)	Flexor and extensor tendons of the hand and wrist	Tenosynovitis, tendon rupture, tendon nodules	GS	Yes	Hypoechoic thickening of the tendon sheath with or without fluid for tenosynovitis; no description for rupture	Binary
Coakley *et al.* [25]	Case–control (unblinded)	RA	28 (14 controls)	TP	Tendon rupture	GS	No	Tendon thickness	Binary (tendon rupture); quantitative (tendon thickness)
Grassi *et al.* [26]	Case–control (unblinded)	RA	20 (20 healthy controls, 1 cadaver)	Flexor and extensor tendons of the fingers	Tendon sheath widening, loss of normal fibrillar echotexture, irregularity of the tendon margins, tendon tear, synovial cyst	GS	Yes	Synovial thickening: well-defined area of increased echogenicity within the tendon sheath; synovial cyst: circumscribed hypoechoic distension of the tendon sheath with well-defined margins and without evidence of contiguous tendon involvement	Binary; quantitative for widening of the tendon sheath
Koski [27]	Case–control (unblinded)	RA (21 p), PsA (2 p), AS (1 p), oligoarthritis (1 p)	25 (35 healthy controls)	Flexor tendons of the toes	Tenosynovitis	GS	Yes	Hypoechoic zone around the tendon within the synovial sheath, tendon thickening, abnormal tendon contour	Binary
Cunnane *et al.* [28]	Case series	RA (five p), PsA (six p), HLA-B27 arthritis (three p), AS (two p), Reiter (one p), BehÇet (one p), SLE (one p)	19	Achilles, TP, peroneal	Tendinitis, tenosynovitis, partial rupture	GS	Yes	Tendon thickening and decrease of echogenicity of the tendon and synovial sheath for tendinitis; focal thickening, focal hypoechogenicity with discontinuity of the tendon fibres or thinning for partial rupture	Binary
Lehtinen *et al.* [29]	Case series	RA	17	TP, peroneal, FHL	Tenosynovitis	GS	Yes	Tendon and/or synovial sheath thickening, increased SF	Semi-quantitative 0–2; quantitative for grading tenosynovial thickening
Olivieri *et al.* [30]	Case–control (asymptomatic contralateral fingers as controls)	SpA	10	Flexor and extensor tendons of the fingers	Flexor tenosynovitis	GS	No	Tendon and synovial sheath thickness, peritendinous soft tissue thickness	Quantitative
Koski [31]	Case–control	RA	25 (30 healthy controls)	Flexor tendons of the toes	Tenosynovitis	GS	No	No description	Binary
Kane *et al.* [32]	Case–control (uninvolved contralateral fingers as controls)	PsA	17	Flexor tendons of the fingers and toes	Tenosynovitis	GS	Yes	Increased diameter of the tendon and synovial sheath with a hypoechoic zone encircling the tendon	Binary; quantitative (tendon diameter)
Swen *et al.* [33]	Case series	RA	21	Wrist extensor tendons	Tendon rupture (partial and complete)	GS	Yes	Tendon structure integrity, separation of the tendon ends	Binary

(continued)

Table 1 Continued

Author	Type of study	Disease	Sample size	Tendons assessed	Tendon lesions assessed	US mode	US definition of lesions	US components of lesion	Quantification system
Premkumar *et al.* [34]	Case–control (blinded)	Arthritis (19 p: 7 RA,12 other arthritis), idiopatic tendinitis (11 p), CTD (1 p)	31 (15 healthy controls)	TP, FDL	Tendinosis, peritendinosis	GS, PD, CD	No	Tendon diameter, tendon echogenicity, peritendinous hypoechoic tissue and fluid, intra- and peritendinous flow	Binary; quantitative (for distinguising normal/abnormal)
Hoving *et al.* [35]	Cohort	RA	46	EPB, APL, ECRB, ECRL, EPL, ED, EDM, ECU, FDP, FDS, FCU, FCR	Tenosynovitis, tendon rupture	GS, CD	No	Tendon sheath thickening, tendon sheath effusion, tendon size	Binary, semi-quantitative 0–3, quantitative for grading tendon sheath thickening
Scheel *et al.* [36]	Case series	RA, gout, RS3PE, ReA	4	Biceps, rotator cuff, flexor and extensor tendons at the wrist, flexor and extensor tendons of the second finger, Achilles, flexor and extensor tendons at the ankle, and peroneal	Tenosynovitis; tendinitis, paratendonitis, tendon tear	GS	No	No description	Binary
Milosavljevic *et al.* [37]	Case–control (unblinded)	PsA	36 (10 healthy controls)	Flexor and extensor tendons of the hand and wrist	Tenosynovitis, tendinitis	GS, PD	Yes	Widening of tendon sheath, tendon widening, loss of normal fibrillar echostructure and irregularity of the tendon margins, tendon and synovial tendon sheath tissue vascularity	Semi-quantitative on GS (0–3) based on synovial sheath and tendon thickness; semi-quantitative on PD (0–3: 0, no detectable signal; 1, $\leqslant$30% of synovial proliferations area; 2, $\leqslant$60% of synovial proliferations area; 3, $>$60% of synovial proliferations area
Naredo *et al.* [38]	Case series	RA (14 p), SpA (2 p), OA (5 p), degenerative shoulder disorder (3 p)	24	Biceps, rotator cuff, flexor and extensor tendons at the wrist, second finger flexor tendon, TA, TP, flexors tendons at the ankle, peroneal and Achilles	Tenosynovitis, tendinosis, calcification, tendon tear, paratenonitis, enthesitis	GS, PD	No	Diagnostic criteria used in practice	Binary
Wakefield *et al.* [39]	Case–control (unblinded)	RA	50 (20 healthy controls)	Flexor and extensor tendons of the fingers	Flexor tenosynovitis, periextensor tendon inflammation	GS	No	No description	Binary
Wiell *et al.* [40]	Case–control (unblinded)	PsA (15 p), RA (5 p)	20 (5 healthy controls)	Second to fifth finger extensor and flexor tendons	Tenosynovitis, insertional changes	GS, PD	Yes	Hypoechoic rim around the flexor tendon with or without PD signal (tenosynovitis); intra-tendinous hypoechoic enlargement and/or intra-tendinous hyperechoic bands with or without acoustic shadow and/or periosteal irregularities and/	Binary

(continued)

Table 1 Continued

Author	Type of study	Disease	Sample size	Tendons assessed	Tendon lesions assessed	US mode	US definition of lesions	US components of lesion	Quantification system
								or intra-tendinous PD signal at the enthuses (insertional changes)	
Baan *et al.* [41]	Case series	RA	30	FHL	Tenosynovitis, tendon rupture	GS, PD	Yes	Fluid around the tendon or presence of PD signal (tenosynovitis); absence of the tendon at the level of the medial malleolus and no motion of the tendon with great toe flexion (tendon rupture)	Binary
Wakefield *et al.* [42]	Case series	RA	22	EDL, EHL, FDL, FHL, TA, TP, PL, PB	Tenosynovitis	GS	Yes	OMERACT definition, 2005 [20]	Binary
Iagnocco *et al.* [14]	Cohort[a]	RA	18	Second, third and fifth finger flexor tendons, extensor and flexor tendons at the wrist	Tenosynovitis	GS, PD	Yes	Hypoechoic area around the tendon within the tendon sheath	Binary; semi-quantitative 0–3 (0: normal; 1: mild change; 2: moderate change; 3: severe change
Iagnocco *et al.* [15]	Cohort[a]	RA	25	Second, third and fifth finger flexor tendons, extensor and flexor tendons at the wrist	Tenosynovitis	GS, PD	Yes	Hypoechoic area around the tendon within the tendon sheath and PD signal in the tenosynovial tissue	Binary; semi-quantitative 0–3 (0: normal; 1: mild change; 2: moderate change; 3: severe change
Naredo *et al.* [16]	Cohort[a]	RA	278	Biceps, flexor and extensor tendons at the wrist, finger flexor tendons	Tenosynovitis	GS, PD	Yes	SF and hypertrophy within the tendon sheath; PD signal within the synovial sheath	Binary; semi-quantitative (0–3) on GS (0: absent; 1: mild; 2: moderate; 3: marked) and on PD (0–3, 0: no synovial flow; 1: $\leqslant$3 isolated signals; 2: $>$3 isolated signals or confluent signal in less than half of the synovial area; 3: signals in more than half of the synovial area
Naredo *et al.* [18]	Cohort[a]	RA	133	Biceps, flexor and extensor tendons at the wrist, finger and toe flexor tendons, TA, TP, peroneal, flexor and extensor tendons at the ankle	Tenosynovitis	GS, PD	Yes	OMERACT definition, 2005 [20]	Binary; semi-quantitative (0–3) on GS (0–3, 0: absent; 1: mild; 2: moderate; 3: marked) and on PD (0–3, 0: no synovial flow; 1: $\leqslant$3 isolated signals; 2: $>$3 isolated signals or confluent signal in less than half of the synovial area; 3: signals in more than half of the synovial area
Backhaus *et al.* [19]	Cohort	RA (91%) and PsA (9%)	120	Wrist flexor and extensor tendons, second and third finger extensor and flexor tendons	Tenosynovitis, paratenonitis	GS, PD	Yes	OMERACT definition of tenosynovitis, 2005 [20]; echo-poor halo around the tendon (paratenonitis)	Binary for GS; semi-quantitative 0–3 for PD tenosynovitis/paratenonitis (0: no signal; 1: up to three signals or two single and one confluent signal; 2: greater than

(continued)

Table 1 Continued

Author	Type of study	Disease	Sample size	Tendons assessed	Tendon lesions assessed	US mode	US definition of lesions	US components of lesion	Quantification system
									Grade 1 to ⩽50% of the area filled with signals; 3: ⩾50% of the area filled with signals
Haavardsholm *et al.* [43]	Cohort	RA	36	Wrist flexor and extensor tendons	Tenosynovitis	GS	No	No description	Semi-quantitative 0–4 (0: none; 1: uncertain; 2: minimal; 3: medium; 4: high amount of hypoechoic material
Suzuki *et al.* [44]	Case series	RA	17	TP, TA, peroneal, Achilles other flexor and extensor tendons around the ankle	Tenosynovitis, enthesitis	GS, PD	Yes	OMERACT definitions, 2005 [20]	Binary
Klauser *et al.* [45]	Case series	RA (16 p), Still's (1 p), scleroderma (1 p), SpA (1 p), overuse tendinosis (5 p)	24	Wrist flexor and extensor tendons	Tenosynovitis	GS, PD, CEUS	Yes	OMERACT definitions, 2005 [20]	Semi-quantitative 0–2 for tenosynovial thickness (GS), extend of vascularity (PD, CEUS), peri- and intra-tendinous vessel detection (PD, CEUS) and intensity of peri- to extra-tendinous vascularity (CEUS); quantitative for grading GS tenosynovial thickening
Naredo *et al.* [49]	Case series[a]	RA	2	ECU	Tenosynovitis	GS, PD	Yes	OMERACT definitions, 2005 [20]	Semi-quantitative (0–3)
Hammer and Kvien [46]	Cohort	RA	20	Wrist: EPB, APL, ECRB, ERCL, EPL, ED, EI, EDM, ECU, FDP, FDS, FCU, FCR, FPL. Ankle: PL, PB, EDL, EHL, TA, TP, FDL, FHL	Tenosynovitis	GS, PD	Yes	OMERACT definitions, 2005 [20]	Semi-quantitative (0–3)
Micu *et al.* [50]	Case series	RA	14	ECU, TP	Tenosynovitis, tendon rupture, tendinosis	GS, PD	Yes	OMERACT definitions, 2005 [20]	Binary
Gutiérrez *et al.* [47]	Case series	RA (18 p), PsA (20 p)	38	ED tendon (at MCP joints)	Peritenon extensor tendon inflammation	GS, PD	Yes	Hypoechoic swelling of the soft tissue surrounding the tendon with or without peritendinous PD signal	Binary
Delle Sedie *et al.* [48]	Case series	PsA	101	TA, peroneal, extensor hallucis, flexor tendons and common extensor tendons	Tenosynovitis, enthesitis	GS, PD	No	Tendon sheath inflammation	Binary

[a]Tendons were not separately evaluated but included in a global score of GS and PD at each studied joint. p: patients; EDL: extensor digitorum longus; EHL: extensor hallucis longus; FDL: flexor digitorum longus; FHL: flexor hallucis longus; TA: tibialis anterior; TP: tibialis posterior; PL peroneus longus; PB peroneus brevis; EPB: extensor pollicis brevis; APL: abductor pollicis longus; ECRB: extensor carpi radialis brevis; ECRL: extensor carpi radialis longus; EPL: extensor pollicis longus; ED: extensor digitorum; EI; extensor indicis; EDM: extensor digiti minimi; ECU: extensor carpi ulnaris; FDP: flexor digiti profundus; FDS: flexor digiti superficialis; FCU: flexor carpi ulnaris; FCR: flexor carpi radialis; FPL: flexor pollicis longus; Hz: hertz; MHz: megahertz; PRF: pulse repetition frequency; dB: decibels.

40, 41, 44–50] and/or CD (2; 6.5%) [34, 35] were used. Contrast-enhanced GSUS (CEUS) was performed in one study [45].

Technical aspects of US machines and scanning method

Table 2 shows data on the US scanning method. A description of the transducer characteristics was provided in all cases. The frequency of the linear transducers was variable (5–18 MHz), being lower in the studies published before 2000. A 3D volumetric probe was also used in one study [49]. Almost half the studies (14; 42.4%) provided information on technical details of the US settings used for B-mode and Doppler mode.

Descriptions of the patient position, anatomic areas scanned and scanning protocol were variable across the studies. The probe placement was longitudinal and transverse in most studies. Twenty-two (66.7%) studies described or referred to a detailed scanning protocol [14–16, 18, 19, 24–28, 30, 32, 34, 36, 37, 39, 40, 44, 46, 47, 48, 50].

Definitions, components and scoring of US tendon lesions

Definitions and components of tendon lesions

Definition of tenosynovitis or other tendon lesion was provided in 23 (69.7%) studies [14–16, 18, 19, 23, 24, 26–29, 32, 33, 37, 40, 41, 42, 44, 45–47, 49, 50]. The OMERACT 2005 definition of tenosynovitis [21] was adopted by eight studies [18, 19, 42, 44, 45, 46, 49, 50] published since 2008 (Table 1).

The most common US components of tendon lesions evaluated were hypoechoic or anechoic synovial sheath widening or thickening, hypoechoic or anechoic tendon sheath effusion, tendon thickness and peritendinous ± intra-tendinous PD or CD Doppler signal. Illustrative images of tenosynovitis on GS and with PD technique are shown in Figs 2 and 3.

Scoring of tendon abnormalities

Most of the studies (20; 60.6%) used a binary (i.e. presence/absence) score for tendon abnormalities. Semi-quantitative scoring systems for tenosynovitis on GS [14–16, 18, 19, 29, 35, 37, 43, 45, 46, 49] were used in 12 (36.4%) studies and for PD or CD modes in 10 (30.3%) studies [14–16, 18, 19, 35, 37, 45, 46, 49]. GS and Doppler findings were graded separately in the above studies. The criteria for grading ranged from purely subjective to criteria based on the measurement of tenosynovial thickness on B-mode and percentage of tenosynovial widening showing PD or CD flow (Table 1).

Four articles on polyarticular PDUS assessment in patients with RA used a global inflammatory score, including IA synovitis and tenosynovitis, for B-mode and PD mode [14, 15, 16, 18].

Metric properties of US

Table 3 shows the metric qualities (i.e. validity, reliability, responsiveness and feasibility) studied in the articles. Twenty-four (72.7%) articles [14, 15, 16, 19, 25, 27, 29–37, 39–45, 46, 48] dealt with construct validity, 14 of which had a blinded design. The comparator most commonly used was the clinical assessment (14; 42.4%) and MRI (10; 30.3%); other comparators were laboratory (8; 24.2%) and X-ray (4; 12.1%). The results of these studies were variable, but in general tendon inflammation was related to other clinical and laboratory parameters of inflammatory activity and US seemed to detect more tendon involvement than clinical assessment. The studies focused on US *vs* MRI in detection of tenosynovitis showed a fair to moderate sensitivity although a high specificity of US [34, 36, 39, 40, 42].

Regarding criterion validity, only one article studied concurrent validity of US in the detection of tendon tears in RA patients who were undergoing hand surgery because of persistent tenosynovitis [33]. One study tested the predictive validity of US synovitis and tenosynovitis in relation to radiographic progression [16]. The latter assessed tenosynovitis as a component of global joint inflammation. Blinded design was reported in both articles. US and MRI showed low sensitivity and high specificity for detecting wrist tendon tears using surgical findings as the gold standard, although the sensitivity for US was better than for MRI [33].

The reliability of US-detected tendon abnormalities was assessed in 12 (36.4%) studies as follows: inter-observer reliability in 11 studies [16, 18, 19, 36, 37, 38, 40, 42, 45, 49, 50], intra-observer reliability in 5 studies [16, 18, 19, 37, 39] and both inter-observer and intra-observer reliability in 4 studies [16, 18, 19, 37]. Inter-observer acquisition reliability was tested in 6 studies [36, 38, 40, 42, 49, 50] and inter- and/or intra-observer reading in 6 studies [16, 18, 19, 37, 39, 45].

Responsiveness of US-detected tenosynovitis was evaluated in seven (21.2%) studies [14–16, 18, 19, 43, 46] and demonstrated mainly in RA patients who had begun a biologic therapy [14–16, 18, 19, 46]. However, in four of these studies [14–16, 18] tenosynovitis was not separately evaluated but included in a global score at each studied joint. One study [46] focused on responsiveness of a comprehensive *vs* a reduced assessment of RA tenosynovitis. Feasibility was tested only in four (12.1%) articles [26, 18, 19, 49].

Discussion

Despite the important role of tenosynovitis and tendon damage in the inflammatory spectrum and functional impairment, respectively, in RA and other chronic inflammatory arthritis [2, 3], most MSUS research on the above diseases has focused on IA synovitis [5–16]. The high image resolution and Doppler sensitivity offered by MSUS technology within the last decade make this imaging modality a potentially powerful tool for evaluating tendon inflammation and damage in both clinical practice and clinical trials. However, before incorporating this into practice and clinical trials, metric properties of MSUS in inflammatory tendon lesions such as validity, reliability, sensitivity to change and feasibility must be investigated.

Table 2 US modes, settings and scanning method

Reference	US mode	US scanning method			
		Probe and settings	Patient position; anatomic area scanned	Probe placement	Scanning protocol
De Flaviis *et al.* [23]	GS	Linear and small part probe; 5–7.5 MHz	Flexion and extension of the wrist and fingers	Longitudinal and transverse	Not described
Fornage [24]	GS	5 and 7.5 MHz	Dynamic examination; dorsal and volar aspect of the wrist and hand	Longitudinal and transverse	Fornage 1988 (book)
Coakley *et al.* [25]	GS	7.5 MHz linear transducer	Position not described; behind the medial malleolus to the navicular tuberosity	Longitudinal	Described
Grassi *et al.* [26]	GS	13 MHz sector transducer	Position not described; dorsal and volar aspect of the fingers	Longitudinal and transverse	Described
Koski [27]	GS	7.5 MHz linear transducer	Position not described; plantar region of the forefoot, MTP joints	Transverse and longitudinal	Described
Cunnane *et al.* [28]	GS	7.5 MHz linear transducer	Description in previous reports	Longitudinal and transverse	Kainsberger 1990 (journal); Mathieson 1988 (journal); Brophy 1995 (journal)
Lehtinen *et al.* [29]	GS	7.5 MHz linear transducer	Position not described	Not described	Not described
Olivieri *et al.* [30]	GS	7.5 MHz linear transducer	Dorsal and volar aspect of the fingers, at rest and in active and passive movement	Longitudinal and transverse	Fornage and Rifkin 1988 (journal)
Koski [31]	GS	7.5 MHz linear transducer	Position not described; plantar region of the forefoot, MTP joints	Longitudinal and transverse	Not described
Kane *et al.* [32]	GS	7.5 or 10 MHz linear transducer (two different machines)	Description in previous report	Longitudinal and transverse	Fornage 1988 (journal)
Swen *et al.* [33]	GS	10 MHz linear transducer	Not described	Longitudinal and transverse	Not described
Premkumar *et al.* [34]	GS, PD, CD	10 MHz small parts transducer; CD and PD gain so that no flow in the cortical bone	Patient in a prone oblique position, ankle slightly elevated on a rolled towel	Longitudinal and transverse	Described
Hoving *et al.* [35]	GS, CD	10 MHz small parts transducer	Dorsal and volar aspect of the hand joints in full flexion and extension	Not described	Not described
Scheel *et al.* [36]	GS	12.5 MHz for wrist/finger, ankle/toe; 10 MHz for shoulder and knee, gain 100%	Not described	Not described	Backhaus 2001 (journal)
Milosavljevic *et al.* [37]	GS, PD	13 MHz linear transducer; PD frequency 7 MHz; Doppler extra low filter; colour gain at a level just below the disappearance of colour noise deep to the cortical bone	Hand in neutral position; dorsal and volar aspect of the wrist and fingers	Longitudinal and transverse	Described

(continued)

Table 2 Continued

Reference	US mode	US scanning method			
		Probe and settings	Patient position; anatomic area scanned	Probe placement	Scanning protocol
Naredo *et al.* [38]	GS, PD	7–14 MHz linear transducer	Not described	Not described	Routine scanning technique in practice
Wakefield *et al.* [39]	GS	10–5 MHz linear hockey-stick transducer	Position not described; dorsal and volar aspect of the fingers	Longitudinal and transverse	Described
Wiell *et al.* [40]	GS, PD	9–14 MHz linear transducer; GS frequency, 14 MHz; PD PRF, 500 Hz	Hands in neutral position; dorsal and volar aspect of the fingers and ulnar and radial aspect of some joints	Longitudinal; in case of doubt transversal view was added	Described
Baan *et al.* [41]	GS, PD	7–13 MHz linear transducer	Neutral position and flexion of the great toe; at the medial malleolus and 6 cm distal and proximal to this point	Not described	Not described
Wakefield *et al.* [42]	GS	10–5 MHz linear hockey-stick transducer	Not described	Not described	Not described
Iagnocco *et al.* [14]	GS, PD	14 MHz linear transducer; PD PRF 700–1000 Hz, Doppler gain 18–30 dB, Doppler low filter	Description in previous reports	Multiplanar	Backhaus 2001 (journal); Schmidt 2004 (journal)
Iagnocco *et al.* [15]	GS, PD	14 MHz linear transducer; PD PRF 700–1000 Hz, Doppler gain 18–30 dB, Doppler low filter	Description in previous reports	Multiplanar	Backhaus 2001 (journal); Schmidt 2004 (journal)
Naredo *et al.* [16]	GS, PD	7–12 MHz linear transducer; PD PRF, 500–1,000 Hz, Doppler low wall filters, dynamic range 20–40 dB, colour gain 18–30 dB	Description in previous reports	Longitudinal and transverse	Naredo 2005 (journal); Naredo 2007 (journal); Scheel 2005 (journal)
Naredo *et al.* [18]	GS, PD	7–12 MHz linear transducer; PD PRF, 500–750 Hz	Description in previous reports	Longitudinal and transverse	Naredo 2005 (journal); Naredo 2007 (journal); Scheel 2005 (journal)
Backhaus *et al.* [19]	GS, PD	Not described	Description in previous reports	Description in previous reports	Backhaus 2001 (journal); Backhaus 2002 (journal)
Haavardsholm *et al.* [43]	GS	8–16 MHz linear transducer	Patient seated with the forearm resting on a small table	Longitudinal and transverse	Not described
Suzuki *et al.* [44]	GS, PD	5–11 MHz linear transducer; GS: frequency, 11.0 MHz; PD: frequency, 6.1; PRF, 15.6–17.3 kHz	Anterior, medial and lateral scans of the ankle in supine position, posterior scan of the heel in prone position; dynamic examination	Multiplanar	Backhaus 2001 (journal)
Klauser *et al.* [45]	CS, PD, CEUS	13 MHz linear transducer; PD: frequency, 10–12.5 MHz; PRF, 750–1000 khz; low wall filter, medium persistence	Not described	Transverse and longitudinal	Not described

(continued)

Table 2 Continued

Reference	US mode	US scanning method			
		Probe and settings	Patient position; anatomic area scanned	Probe placement	Scanning protocol
Naredo *et al.* [49]	GS, PD	3D volumetric trasducers; GS: frequency, 15 MHz; dynamic range, 66 dB PD: frequency, 7.7 MHz; PRF, 900 Hz; gain, 39 dB	Not described	Multiplanar	Volumetric acquisition
Hammer and Kvien [46]	GS, PD	5–13 MHz linear transducer; PD: frequncey, 7.3 MHz; PRF 391 Hz	Wrist: resting the hand on a small table; ankle: lying on a bench with the knees flexed	Longitudinal and transverse	Described
Micu *et al.* [50]	GS, PD	8–14 MHz linear transducer; GS: dynamic range 72 dB, frequency 12–14 MHz, gain 66 dB; PD: frequency 6.3–7.5 MHz, gain 41 dB, PRF 500–750	Position not described; ulnar styloid process, medial malleolus	Longitudinal and transverse	Described
Gutiérrez *et al.* [47]	GS, PD	6–18 MHz linear transducer, PD: frequency, 9.1–11.1 MHz; PRF 750 Hz; persistence 4; wall filter 3; gain set just below the level at which colour noise appeared underlying bone	Patient seated with hands in prone position	Longitudinal and transverse (with slightly movement radial to ulnar, proximal to distal)	Described
Delle Sedie *et al.* [48]	GS, PD	14 MHz linear transducer; PD: frequency, 7.5 MHz; PRF 500 Hz	Patient in supine position with the foot in neutral extended position (in prone position for the flexor tendons)	Multiplanar	Backhaus 2001 (journal)

Hz: hertz; MHz: megahertz; PRF: pulse repetition frequency; dB: decibels.

Fig. 2 Panoramic US image on B-mode of a finger tenosynovits. Hypoechoic widening of the synovial sheath (s) superficial and deep to the tendon (t) is seen. pp: proximal phalanx; mp: middle phalanx; dp: distal phalanx.

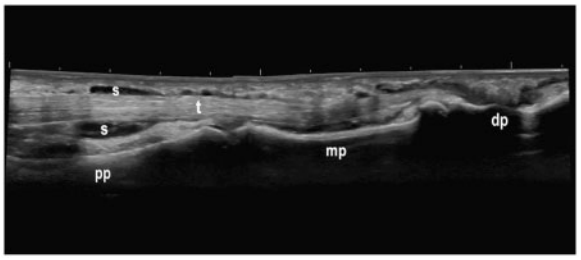
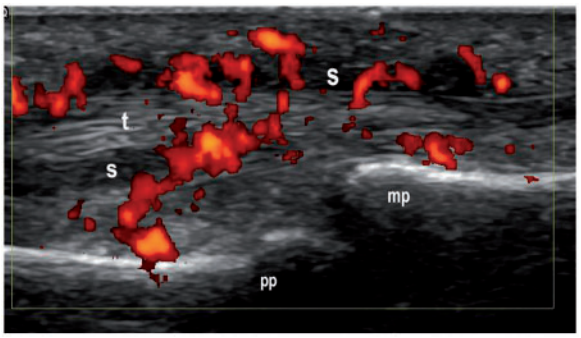


Fig. 3 Longitudinal US image with PD mode of a finger tenosynovitis. Hypoechoic thickening of the synovial sheath (s) that surrounds the tendon (t) and pathological Doppler signal within the synovial sheath and the tendon are seen. pp: proximal phalanx; mp: middle phalanx.



In this literature review, most published articles were case series or case–control studies describing tenosynovitis in RA patients. As expected, most of them studied hand and/or foot tendons because they are frequently involved in inflammatory joint diseases as well as being easily accessible for US. As highly sensitive Doppler technique has only been available for the last 5–10 years, the majority of older articles used only B-mode, whereas the most recent studies have incorporated PD or CD modes. In general, the articles provided details regarding the probe, US settings and/or scanning method, although in many of these details were insufficiently described to allow comparisons between studies.

Descriptions of US abnormalities were relatively homogeneous across the studies. The most commonly described component of US tenosynovitis was a hypoechoic widening or thickening of the tendon sheath based on the subjective comparison with normal or asymptomatic tendons or based on an arbitrary sheath thickness measure determined as a cut-off between normality and pathology. Inflammatory changes in the tendon substance (e.g. tendon thickening and/or hypoechogenicity) were also evaluated in some articles. Within the past 5 years the articles have tended to use a more formal definition of tenosynovitis, mainly the OMERACT definition [21]. Some studies attempted to quantify tenosynovitis on B-mode and Doppler mode, most of these in a subjective manner. Only half among these tested inter-observer and/or intra-observer reliability for the proposed scoring system. A distinction between partial and complete tendon tear was applied in some studies. However, none of these studies attempted to grade early tendon damage. Thus reproducible scoring systems for tendon inflammation and damage should be agreed on before their application in multicentre studies.

Regarding metric properties, the majority of studies dealing with validity assessed US tendon lesions, mainly tenosynovitis *vs* clinical inflammatory findings at the joint or patient level as constructs. As shown for synovitis [5–8], most studies reported higher sensitivity of US compared with physical examination in the detection of tenosynovitis.

When MRI was used as construct, US seemed to be clearly less sensitive for detecting tenosynovitis. This is surprising considering the general opinion based on experience of the high capability of US to evaluate both tendon and tenosynovial inflammatory changes in superficial anatomic areas. It is likely that refinement of the scanning technique (e.g. dynamic examination of tendons) and further knowledge of anatomic details related to tendons and tendon sheaths (e.g. retinaculae, pulleys) would improve the above results.

There was very little information regarding the criterion validity of US compared with gold standards such as surgical findings or histology in the detection of inflammatory tendon lesions. The difficulties of conducting these types of studies due to the scarcity of patients with biopsy or surgery indication in clinical practice may explain this fact.

Although the reliability of US in assessing inflammatory tendon lesions was tested in a number of monocentric studies, further assessment of intra- and inter-observer reliability for definitions, image acquisition and scoring systems is necessary before its widespread application in multicentric studies.

US-detected tenosynovitis seemed to be responsive to effective treatment for RA in the few cohort studies that have been published so far. However, more studies are needed to establish the sensitivity to change of US in relation to its intra-observer reproducibility in the quantification of inflammatory tendon lesions.

In conclusion, US seems a promising tool for evaluating and monitoring inflammatory tendon lesions but needs greater standardization in definitions, scanning method and scoring systems as well as further testing of its metric properties before it can be fully implemented in clinical practice and trials. There is also still insufficient data to support the feasibility of US detection and scoring of tendon lesions. Currently the OMERACT MSUS group is generating agreed definitions and scoring systems for tenosynovitis and tendon damage in RA whose metric properties will be tested in the near future.

Table 3 Metric properties assessed and quality score of the studies

Reference	Blinded design	Validity			Reliability		Responsiveness	Feasibility
		Construct	Criterion	Comparator	Intra-observer	Inter-observer		
De Flaviis *et al.* [23]	NA	No	No	No	No	No	No	No
Fornage [24]	NA	No	No	No	No	No	No	No
Coakley *et al.* [25]	No	Yes	No	Clinical, X-ray	No	No	No	No
Grassi *et al.* [26]	NA	No	No	No	No	No	No	Yes
Koski [27]	No	Yes	No	Clinical	No	No	No	No
Cunnane *et al.* [28]	NA	No	No	No	No	No	No	No
Lehtinen *et al.* [29]	Yes	Yes	No	Clinical, MRI	No	No	No	No
Olivieri *et al.* [30]	Yes	Yes	No	MRI	No	No	No	No
Koski [31]	No	Yes	No	Clinical	No	No	No	No
Kane *et al.* [32]	No	Yes	No	X-ray	No	No	No	No
Swen *et al.* [33]	Yes	Yes	Yes (criterion)	MRI (construct), surgery (concurrent)	No	No	No	No
Premkumar *et al.* [34]	No	Yes	No	MRI	No	No	No	No
Hoving *et al.* [35]	No	Yes	No	MRI	No	No	No	Yes
Scheel *et al.* [36]	Yes	Yes	No	MRI	No	Yes (acquisition reliability) (multi-examiner)	No	No
Milosavljevic *et al.* [37]	Yes	Yes	No	Clinical, laboratory, X-ray	Yes (reading reliability)	Yes (reading reliability)	No	Yes
Naredo *et al.* [38]	Yes	No	No	No	No	Yes (acquisition reliability) (multi-examiner)	No	No
Wakefield *et al.* [39]	Yes	Yes	No	MRI	Yes (reading reliability)	No	No	No
Wiell *et al.* [40]	Yes	Yes	No	MRI	No	Yes (acquisition reliability)	No	No
Baan *et al.* [41]	No	Yes	No	Clinical, X-ray	No	No	No	No
Wakefield *et al.* [42]	Yes	Yes	No	MRI	No	Yes (acquisition reliability)	No	No
Iagnocco *et al.* [14]	Yes	Yes	No	Clinical, laboratory	No	No	Yes	No
Iagnocco *et al.* [15]	Yes	Yes	No	Clinical, laboratory	No	No	Yes	No
Naredo *et al.* [16]	Yes	Yes	Yes (predictive)	clinical, laboratory (construct); X-ray (predictive)[a]	Yes (reading reliability)	Yes (reading reliability)	Yes	No
Naredo *et al.* [18]	Yes	No	No	No	Yes (reading reliability)	Yes (reading reliability)	Yes	Yes
Backhaus *et al.* [19]	No	Yes	No	Clinical, laboratory	Yes (reading reliability	Yes (reading reliability	Yes	Yes
Haavardsholm *et al.* [43]	Yes	Yes	No	Clinical, laboratory, MRI	No	No	Yes	No
Suzuki *et al.* [44]	No	Yes	No	Clinical, laboratory	No	No	No	No
Klauser *et al.* [45]	No	Yes	No	CEUS	No	Yes (reading reliability)	No	No
Naredo *et al.* [49]	Yes	No	No	No	No	Yes (acquisition and reading reliability)	No	Yes
Hammer and Kvien [46]	Yes	Yes	No	Clinical, laboratory	No	No	Yes	No
Micu *et al.* [50]	Yes	No	No	No	No	Yes (acquisition reliability)	No	No
Gutiérrez *et al.* [47]	Yes	No	No	No	No	No	No	No
Delle Sedie *et al.* [48]	Yes	Yes	No	Clinical	No	No	No	No

[a]Tendons were not separately evaluated but were included in a global score of GS and PD at each studied joint. NA: not applicable.

Rheumatology key messages

- This is the first systematic literature review on US assessment of tendon lesions in inflammatory arthritis.
- US seems a promising tool for evaluating inflammatory tendon lesions.
- Further US validation is necessary for implementation in clinical practice and trials.

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Supplementary data

Supplementary data are available at *Rheumatology* Online.

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